



Shine like metal: an experimental approach to understand prehistoric graphite coated pottery technology



Attila Kreiter^{a,*}, Szabolcs Czifra^a, Zsolt Bendő^b, Jánosné Egri Imre^a, Péter Pánczél^a, Gábor Váci^c

^a Hungarian National Museum National Heritage Protection Centre, H-1113 Budapest, Daróci út 3, Hungary

^b Eötvös Loránd University, Institute of Geography and Earth Sciences, Department of Petrology and Geochemistry, H-1117 Budapest, Pázmány Péter sétány 1/C, Hungary

^c Eötvös Loránd University Institute of Archaeological Sciences, H-1088 Budapest, Múzeum krt. 4/B, Hungary

ARTICLE INFO

Article history:

Received 24 February 2014

Received in revised form

21 May 2014

Accepted 19 July 2014

Available online 4 August 2014

Keywords:

Graphite coating

Firing technology

Surface treatment

Experimental archaeology

SEM

Late Bronze Age

ABSTRACT

In the Late Bronze and Early Iron Ages, so-called graphite-coated vessels were ubiquitous in the Carpathian Basin. Studies on graphite-coated vessels are usually carried out from a typological point of view, describing the shape and decoration of such wares and assessing the effects that co-existing cultural groups may have had on each other. Even though the practice of graphite coating had been present in East-Central Europe for several centuries, the way graphite coating was produced has never been investigated systematically. Technological study of graphite coating can, however, highlight interesting details about this practice and the high skill and knowledge of potters that was necessary for this type of ceramic production. In this study, a methodology of making graphite coated vessels, and in turn achieving a metallic luster, is presented through a range of experiments. The results are compared with graphite coating found on archaeological ceramics from a Late Bronze Age site. The experiments point out that graphite coating can be achieved in several different ways; however, only a limited number of technological choices would result in highly metallic luster. During the experiments different graphite coating techniques were tried which elucidate the possible ways prehistoric potters utilized graphite, surface treatments and firing conditions.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction: background to graphitic pottery

Graphite-decorated pottery is a distinctive type of ceramic ware in European prehistory which first appeared in Middle Neolithic cultures of the Balkans and Central Europe (von Carnap-Bornheim, 1998, 594). Graphite was first used for painting motifs on vessels, and the appearance of this practice seems to be associated with Neolithic black/brown/red painted pottery (Vajsov, 2007, 98). Rarely, graphite also appeared on burnished vessel surfaces and as tempering material in Central Europe, in the Linear Pottery Culture (Pechtl and Eibl, 2011, 394–396). Graphite painting was a dominant decorative method for most of the Chalcolithic cultures of the East Balkan region, however later it gradually disappeared

(Papadopoulos, 2007). Graphite-decorated pottery also occurred sporadically in the Early and Middle Bronze Ages, but until the Late Bronze Age graphitic techniques were strongly bound to the geological sources of graphitic rocks (e.g. Bulgaria, Moravia in Czech Republic and south Bavaria in Germany) (von Carnap-Bornheim, 1998, 594; Leshtakov, 2004).

The use of graphite in Late Bronze Age pottery decoration shows a swiftly increasing tendency. The appearance of burnished surface treatment associated with graphite and the newly performed graphite coating technique can be dated between 1300 and 1250 BC (Bz D) in the Eastern Alpine regions and in the Carpathian Basin. In the second half of the 13th century BC graphite coating/burnishing became a widely used surface treatment technique: graphite-coated/burnished pottery appears in large numbers in the tumulus burials of the eastern Alpine area (Burgenland) and in the western and eastern parts of Hungary (Transdanubia, Great Hungarian Plain) (Kovács, 1975, 49; Lochner, 1986a, 271; Kustár, 2000, 24). Graphite appears especially on table wares (bowls, jugs, mugs, cups) and mixing vessels (deep bowls). Presumably, these fine-made vessels were the representative elements of the *table-sets*

* Corresponding author.

E-mail addresses: attila.kreiter@mnm-nok.gov.hu (A. Kreiter), czifra_sz@yahoo.com (Sz. Czifra), bendozs@caesar.elte.hu (Zs. Bendő), imrene.egri@mnm-nok.gov.hu (J. Egri Imre), peter.panczel@mnm-nok.gov.hu (P. Pánczél), vaczigabor@gmail.com (G. Váci).

of houses (Helgert, 1995, 214–215; Nebelsick, 1997, 377–378; V. Szabó, 2004, 89–90), but these ceramics were neither unique nor special pieces of Late Bronze Age households. Therefore, it is probable that graphite-coated/burnished vessel-sets found in burial mounds were accessories of funeral feasts (Kustár, 2000, 22–24; Váczi, 2013a, 826). Based on the burials and depots of the Bz D period (13th century BC) it seems that weapons, jewelry and dress fittings and ornaments were the primary means of social representation in the Late Bronze Age (Váczi, 2013b, 221).

Metal vessels are absent in household assemblages of the Bz D period, therefore graphite-coated ceramics, imitating the texture and appearance of metal vessels, could have been the most prominent instruments of social representations at feasts. Moreover, in the majority of cases graphite had to be imported and the production of graphite-coated vessels required special knowledge. These characteristics render graphite-coated vessels to be a special group of ceramics.

Even though it is widely assumed that graphite-coated vessels may have imitated metal vessels, no detailed analysis has been carried out to establish the assumed relationship between graphite coating and metal vessels. There are no direct archaeological data referring to how the graphite-coating technique appeared in the Carpathian Basin, and neither is it known how graphite was obtained and utilized. Based on dress fittings and ornaments, jewelry and weapons of western Hungarian burials, an intensive relationship and exchange network must have existed between the Carpathian and Moravian Basins in the Bz D period (Váczi, 2013b, 225, Fig. 8). It is very probable that in this period graphite reached the Carpathian Basin through this exchange network. It must be noted that Moravia, as the acquisition area for graphite, also seems to be important in the Celtic period (Kreiter et al., 2013b).

After a short decline, graphite-coated pottery became abundant again in the East-Alpine region and in the neighboring territories in the final phase of the Late Bronze Age (Ha B), around 1000 BC (Říhovsky, 1982, 70). Besides making the whole vessel surface graphitic, striped decoration made by graphite, which became characteristic in the Early Iron Age, also appeared (Podborský, 1970, 65, Abb. 12:1, 21; Lochner, 1986b, 305). Graphite polishing/burnishing became one of the most popular decorating techniques in the Early Iron Age of Central and East-Central Europe (Dobiat, 1980, 127). In the Ha C period (c. 800–650 BC), besides graphite-coating graphite-painting also appeared. In the latter case it seems that graphite was applied on vessel surfaces similarly to painting, in a liquid form as graphitic suspension (Trebsche, 2011, 449–451). Later, during the Ha D period (c. 650–475 BC), polished or drawn graphitic grid patterns represent the most common decorative element in the local variants of the East Hallstatt culture that played a key role in the spread of this type of ceramic further to the east in the neighboring territories (Kreiter et al., 2013a).

The Celtic period brought considerable changes in the use of graphite; it was used as tempering material, which was unprecedented earlier, and the use of graphite-coating/decorating techniques decreased then later disappeared. The Celts started using graphite during the early La Tène period (Jerem and Kardos, 1985), but this practice became more common during the early LT B2 (beginning of the 3rd century BC) in the Carpathian Basin (Szabó, 2007, 317–318). From this period graphite-tempered pottery was a substantial element of Central European Celtic pottery assemblages right up until the decline of the Celtic world (first half of the 1st century AD in Hungary) (Trebsche, 2011). Curiously enough, as opposed to many other pottery forms and techniques, Celtic graphite-tempered wares were not adopted for use by the Romans. Since Celtic graphite-tempered pottery technology was discussed elsewhere (Kreiter et al., 2013b) we do not deal with this subject here.

According to the above, several methods of graphite decoration can be distinguished and these techniques could also be combined. Researchers considered that, if the raw material was pure enough, graphite could have been rubbed on the surface of vessels or it could have been used as a crayon. Otherwise it may have been applied as liquid suspension (Frierman, 1969, 43; Evans, 1986, 397; Yiouni, 2000, 209; Vajsov, 2007, 98; Trebsche, 2011, 449–451). Graphite slip is assumed to be used for coating from the Late Bronze Age to achieve a metallic shine, however it is not underlined scientifically how graphitic slip was made and how one may distinguish between graphitic slip, graphite burnishing and other ways of graphite application. Several graphite prisms are known at sites, far away from the geological sources of graphite (e.g. Gróh, 1984, 61, Fig. 6.13–15; Gáti, 2009, 66, Fig. 4.12–13), which may reinforce the above-mentioned existence of burnishing/drawing/polishing methods, especially in the Early Iron Age and sheds further light on exchange networks.

The use of graphite for ceramic production, since it burns off easily, required a very well controlled firing technology which may have been different from the previous practice of vessel firings; thus its utilization resulted in the emergence of new ceramic styles characterized by black vessels (Vajsov, 2007, 98). The firing temperatures of graphite-coated/decorated ceramics from Chalcolithic and Iron Age sites seem to be below 850 °C but in some cases below 650 °C (Maniatis and Tite, 1981, 75; Jerem and Kardos, 1985, 69; Gebhard et al., 2004, 210; Havancsák et al., 2009, 48–49; Kreiter et al., 2013a, 485, 487).

Researchers agree that graphite-coated/decorated vessels had to be fired under reducing conditions (Yiouni, 2000, 209; Berdelis, 2002) but no detailed study explains the whole production sequence that was necessary to achieve a lustrous black vessel with metallic appearance.

In the light of the above it is clear that several interpretations were made about graphite coating/decoration. However, no clear technological descriptions exist on the whole production sequence of graphite coating/decoration. Therefore, in the following sections the results of a set of experiments are introduced on different ways of graphite coating.

2. Methodological approach of the experiment

The experiment was carried out on small cylindrical vessels made by the authors (Fig. 1.1) from commercially available clay called Kishajmás type, which is widely used in Hungary by potters. No attempt was made to reproduce archaeological vessel forms; the aim of this experiment is to assess how graphite coating was produced and how such vessels could have been fired. The prepared vessels provide a large enough surface to observe the results of the experiment. The raw graphite used for this experiment was obtained from Ménfőcsanak–Széles földék (N–W Hungary) archaeological site, the graphite lumps were found in Celtic features (3rd century BC) (Fig. 1.2). The experiment was designed to combine different graphite coating methods, surface treatments, firing temperatures and firing circumstances. As a result, a total of 27 graphite-coated vessels were manufactured. The processes they were subjected to are summarized in Appendix 1.

During the experiment the following questions were examined:

The first question concentrated on how graphite may have been applied on vessel surfaces by prehistoric potters. Was graphite applied in powder form or as suspension, or were graphite lumps rubbed on the surface? Was graphite applied on a dry or leather hard vessel surface and was graphite applied before or after firing?

The second question regarded the surface treatments of vessels, which seem vital to achieve metallic luster. It was investigated

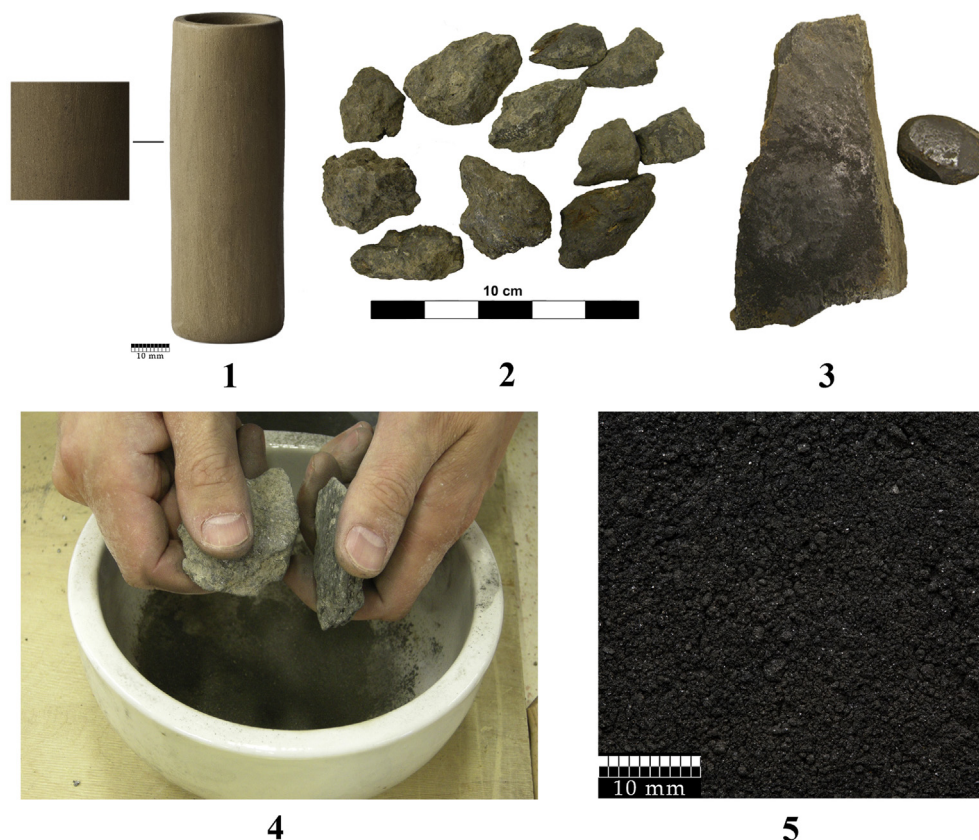


Fig. 1. 1. Original leather hard vessel; 2. Raw graphite used for the experiment; 3. Grinding stone and raw graphite (note the rounded edges of the graphite after rubbing it against the grinding stone); 4. Making graphite powder by rubbing graphite lumps together; 5. Graphite powder gained by grinding.

whether surface treatments were applied before or after graphite coating, and whether on dry, leather hard or perhaps fired vessels.

The third question focused on the firing temperature and atmosphere to be necessary for graphite-coated wares, since graphite burns off easily if the atmosphere is inappropriately controlled (Kreiter et al., 2013b).

2.1. Making graphite powder and graphitic suspension

During the experiment graphite powder and graphitic suspension were used. Graphite powder (Fig. 1.5) can be produced in several ways: graphite is relatively soft (Mosh 1–2), therefore graphite powder could be made without difficulty by rubbing a graphite lump against a sandstone grinding stone (Fig. 1.3) or rubbing graphite lumps together (Fig. 1.4). The result, in both cases, was a fine graphite powder (Fig. 1.5). We also ground graphite lumps in a modern mortar. This way of grinding could also have been achieved by prehistoric potters using a grinding stone and a grinding lap. The result of the different ways of achieving graphite powder was similar; in all cases a suitable-sized graphite powder was gained. Suspension was made by mixing 10 g clay (the same type used for the vessels) with 10 g graphite powder and mixed with water until it became a suspension suitable for covering a vessel. Another type of suspension was also made by mixing graphite powder with water only.

2.2. Applying graphite on vessel surfaces

Graphite powder was applied on both dry and leather hard vessels prior to firing and also after firing. We also made vessels

covered with different types of suspensions, and raw graphite lumps were also used (like crayons), to make vessels graphitic:

-Applying graphite powder on leather hard vessels: Graphite powder was sprinkled on vessel surfaces and slightly rubbed by hand followed by other, if any, surface treatments (see Section 2.3, Samples 1–3, 5–15, 20–22). Leather hard vessels seem to be ideal candidates for graphite coating because graphite adhered to the vessel surfaces properly.

-Applying raw graphite lumps on leather hard vessels: A raw graphite lump was rubbed on vessel surfaces (Samples 4, 16–18) during which graphite should have worked as a burnishing tool, however, burnishing with graphite lumps turned out to be a disadvantageous practice. Raw graphite had sharp edges, which scratched the vessels; therefore without modification they are unsuitable for rubbing. Their edges had to be ground down on a grinding stone or graphite lumps could be rubbed against each other to create a rounded surface. This process is time consuming and seems unnecessary since grinding a graphite lump on a stone or against each other itself resulted in graphite powder that could easily be used for vessel coating very efficiently. However, this was not the main problem with raw graphite. During the rubbing of a graphite prism against the vessel surface its pores became filled with clay and the graphite became unsuitable for this practice in a matter of seconds; graphite just slid on the vessel surface without making it properly graphitic. This problem could be solved by rubbing the graphite on a grinding stone to create a *fresh surface* but after a few rubbings the graphite again became unsuitable for this purpose. Another problem with raw graphite is that its impurities, such as the rock incorporating graphite, calcareous and

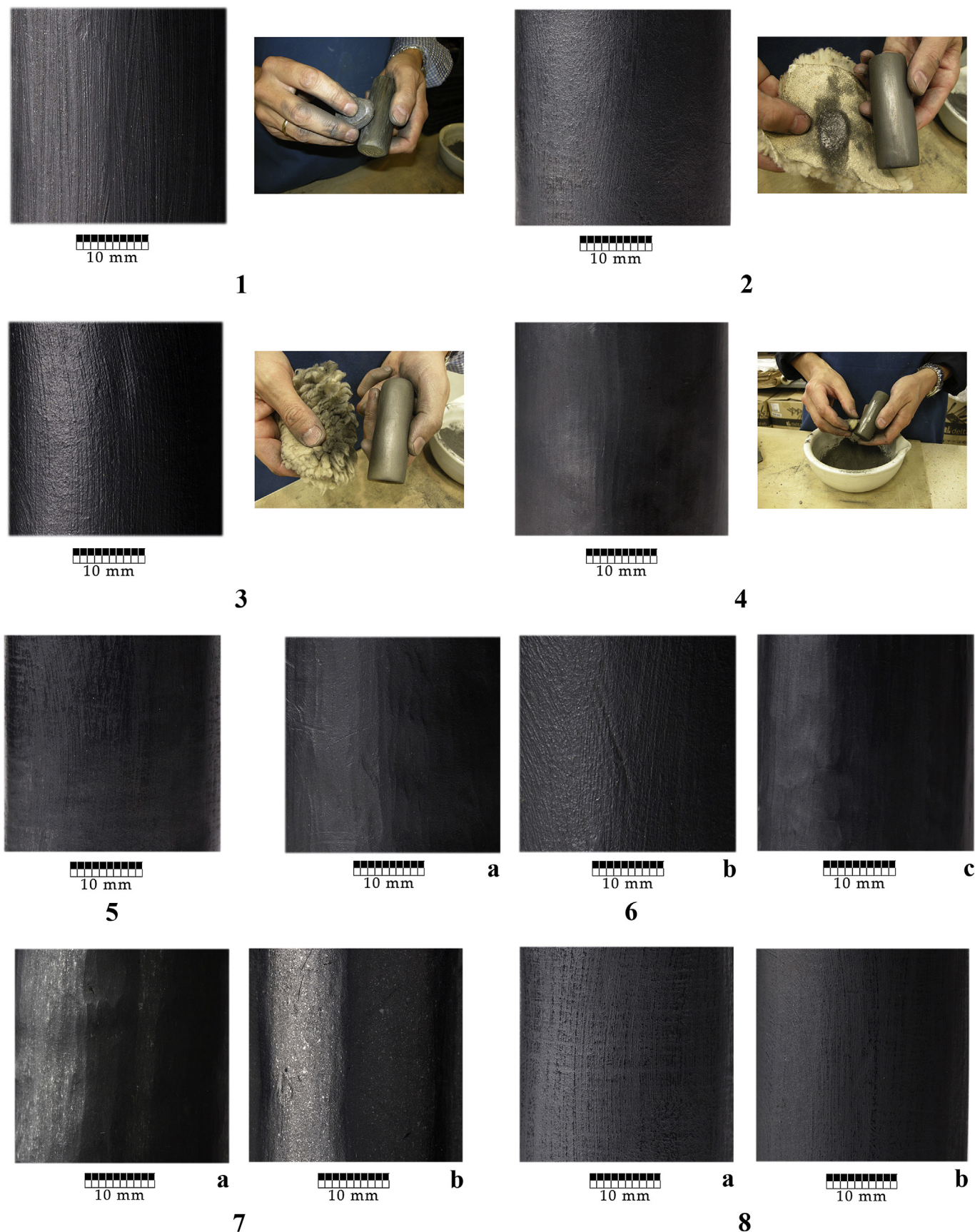


Fig. 2. Results of different surface treatments. 1. Burnished with raw graphite (Sample 17); 2. Polished with sheep leather (Sample 14); 3. Polished with sheep wool (Sample 12); 4. Burnished with pebble (Sample 7); 5. Dried sample covered with graphite powder and burnished with pebble (Sample 19); 6. Samples which were first surface-treated then were

iron oxide veins/inclusions within the graphite lump, scratched the surface of the vessel. In summary, graphite lumps turned out to be the least suitable candidates for graphite coating; their utilization was much more time consuming, less effective and visually less appealing.

-Applying graphitic suspension on leather hard vessels: A leather hard vessel (Sample 23) was coated with graphitic suspension made of clay (10 g clay + 10 g graphite powder + water). A further vessel (Sample 27) was coated with a mixture of graphite powder and water (10 g graphite powder + water). Both suspensions adhered to the vessel surfaces properly.

-Applying graphite powder on a dried vessel with no surface treatment: A dried vessel (Sample 19) with no surface treatment was sprinkled with graphite powder and rubbed by hand. This vessel turned out to be unsuitable for graphite coating; graphite did not adhere properly on its surface. Therefore, the experiment was not continued on dried vessels.

-Applying graphite powder on fired vessels with no surface treatment: Graphite powder was applied on vessels (Samples 24–25) already fired in reducing conditions. These vessels did not have surface treatments prior to firing. After firing they were sprinkled with graphite powder, rubbed by hand and one of them was burnished with pebble (24) and the other with sheep leather (25) (see Section 2.3). The graphite did not adhere to the vessels properly – it could be rubbed off. Therefore, the experiment was not continued on fired vessels.

2.3. Surface treatments

Surface treatments were applied prior to or after graphite coating, or after firing as well, in order to assess the traces of different surface treatments and, in turn, to understand which method may have been used by prehistoric potters to achieve the most lustrous vessel surface. The most common objects were used for surface treatments, which were readily available for prehistoric potters, such as pebble, sheep leather, sheep wool and raw graphite. The term burnishing is used for surface treatment with hard objects such as pebble and raw graphite. The term polishing is used for surface treatment with soft objects such as sheep leather and sheep wool.

-Surface treatment in the case of using a raw graphite lump (Fig. 2.1): When a graphite lump was used like a crayon to make a vessel surface graphitic (Samples 4, 16–18), no further surface treatment was applied; since graphite behaved as a burnishing tool, however, as it was mentioned above, it rendered vessel surfaces very scratchy and streaky.

-Surface treatment of leather hard vessels after graphite powder coating: After sprinkling and rubbing graphite powder onto vessel surfaces with the hand the following surface treatments were applied in order to distribute graphite evenly, to increase cohesion between graphite and clay, and to increase the metallic luster of vessels:

- polished the vessels with sheep leather (Fig. 2.2) (Samples 3, 13–15)
- polished the vessels with sheep wool (Fig. 2.3) (Samples 2, 10–12)
- burnished the vessels with pebble (Fig. 2.4) (Samples 1, 5–9)

The use of sheep leather and wool for polishing made surfaces fairly shiny and lustrous, but also rather scratchy and streaky,

rendering the end product visually less appealing. The most lustrous and metallic appearance of the surfaces was undoubtedly achieved by pebble burnishing.

-Surface treatment of dried vessels after graphite powder coating (Fig. 2.5): One vessel (Sample 19) was dried, then graphite powder was sprinkled on its untreated surface, it was rubbed by hand and burnished with pebble. The pebble made the dry surface very scratchy; graphite did not adhere to the vessel properly.

-Surface treatment prior to graphite powder coating on leather hard vessels (Fig. 2.6): One leather hard vessel (Fig. 2.6a, Sample 20) was first burnished with pebble then, while it was still leather hard, it was sprinkled with graphite powder and rubbed with the hand. This sample shows a similar luster to those which were first sprinkled with graphite powder then were burnished with pebble. Another leather hard vessel (Fig. 2.6b, Sample 22) was polished with sheep leather then, while it was still leather hard, it was coated with graphite powder and rubbed with the hand. This sample shows similarity to other leather-polished samples. It seems that graphite can be applied before or after surface treatment as long as the surface is still leather hard; the vessel surfaces would be lustrous and graphite would adhere to the surface properly. The above-mentioned vessels were then fired in reducing conditions (see Section 2.4). One sample (Fig. 2.6c, Sample 26) was burnished with pebble then was fired in reducing conditions followed by graphite powder coating, which was rubbed on the surface with the hand. This practice seemed futile: similarly to Samples 24–25, graphite did not adhere properly to the surface; it could be rubbed off.

-Surface treatment after graphitic suspension coating (Fig. 2.7): One vessel (Fig. 2.7a, Sample 23) was coated with graphitic suspension made of clay. Another vessel (Fig. 2.7b, Sample 27) was coated with a mixture of graphite powder and water. After the vessels became leather hard both were burnished with pebble. These vessels show high metallic luster, similar to the samples which were coated with graphite powder and burnished with pebble. Both types of suspensions bonded similarly to vessel surfaces and both have similar metallic luster. It seems that if clay-based graphitic suspension is used (Sample 23), the ratio of graphite to clay should be at least 50%. This amount of graphite in the mixture ensures a similar appearance to graphite powder coating.

-Surface treatments after firing (Fig. 2.8): The surfaces of two vessels (Samples 24–25) were untreated before firing. After firing they were sprinkled with graphite powder then one of them (Fig. 2.8a, Sample 24) was burnished with pebble and the other (Fig. 2.8b, Sample 25) was polished with sheep leather. These processes resulted in scratched, less lustrous surfaces. Moreover, graphite did not adhere to the vessel surfaces properly, both vessels left graphitic marks on the hand, and the graphite could be rubbed off.

2.4. Firing atmospheres and temperatures of graphite coated vessels

Firing graphitic pottery is a tricky business since graphite burns off easily at a relatively low temperature (Kreiter et al., 2013b, 176). Even though it is well-known that graphite burns off at a relatively low temperature in oxidizing circumstances, we still carried out experiments under such conditions in order to assess how different

covered with graphite powder: 6a. Burnished with pebble prior to graphite coating and firing (Sample 20), 6b. Polished with sheep leather prior to graphite coating and firing (Sample 22), 6c. Burnished with pebble, fired, then covered with graphite powder and rubbed with the hand (Sample 26); 7. Suspension-coated vessels which were burnished with pebble: a. Suspension made from clay (Sample 23), b. Suspension made with water (Sample 27); 8. Surface treatments after firing of graphite-coated samples: a. Burnished with pebble (Sample 24), b. Polished with sheep leather (Sample 25).

technologies, in particular surface treatments, affect the cohesion between graphite and the vessel surface. The firings were performed in a Nabertherm L15/12/320 type electric kiln. No attempt was made to reproduce prehistoric firing conditions in pit or open firing. The aim was to reproduce and maintain the most desired firing circumstances in order to achieve a high metallic luster. Appendix 1 shows the firing atmosphere and temperature of each sample while Table 1 shows the heating parameters of the vessels.

Four samples with different surface treatments (Samples 1–4) were fired at 700 °C in oxidizing condition (Fig. 3). Graphite burned off the surfaces of the vessels almost completely; however, in the case of pebble-burnished sample (Fig. 3.1) some graphite still remained on the surface and the leather-polished one also showed graphite remains (Fig. 3.3). The results indicate that the cohesion between graphite and clay was the strongest in the case of pebble burnishing. Since graphite disappeared at a relatively low temperature in oxidizing conditions we did not fire further vessels at higher temperatures under this firing condition.

The experiment was continued with reducing firing conditions. Vessels with different surface processing were fired at 700, 750 and 800 °C. Reducing condition was achieved by placing the vessels into heat resistant steel boxes, in which the vessels were covered with wood chipping then the boxes were covered with a steel lid (Fig. 4). Vessels fired in this way showed metallic luster at all the above-mentioned temperatures and their graphite coating also remained intact (Fig. 5). Since graphite remained on the vessels in *mint* condition in reducing firing, we fired further two pebble burnished vessels, also in reducing conditions, at temperatures of 900 and 1000 °C in order to test how increased temperature affects graphite coating in terms of texture and luster. We did not fire graphite-coated vessels at higher temperatures because the available data suggest that prehistoric potters usually fired their graphitic vessels between 700 and 900 °C. Graphitic luster remained intact at both 900 and 1000 °C, although at 1000 °C the top and bottom of the sample became slightly oxidized as a result of uneven distribution of wood chipping which covered the sample. Nevertheless, on the majority of this vessel graphite also remained in perfect condition. This indicates that graphite-coated vessels could be fired at a wide range of temperatures as long as the atmosphere remains completely reduced.

The different firing temperatures do not seem to affect the metallic appearance of the vessels; however, it seems that it is the surface treatment that is vital to achieving a metallic luster. It must also be noted that after firing the graphitic surfaces did not leave smudges on the hand; graphite adhered to the surfaces properly. Vessels, however, which were coated with graphite after firing left smudges on the hand and the graphite could be rubbed off the vessel surfaces. Therefore, it seems that reducing atmosphere is essential to *finalize* the cohesion between graphite and vessel surface, otherwise graphite can be rubbed off or would be worn off during the use of the vessel.

3. Correlating the results with archaeological samples

In order to understand the practice of graphite coating further, the results of the experiments were compared with graphite

coating on archaeological ceramics by using an AMRAY 1830 scanning electron microscope (SEM) with EDAY PV9800 Energy-dispersive X-ray spectroscope. Graphite coating was examined on two experimental samples, which show the greatest similarity to archaeological samples in terms of texture and luster:

Sample 6: graphite powder was sprinkled on a leather hard surface then was burnished with pebble and fired in reducing conditions at 750 °C;

Sample 23: it was coated with graphitic suspension made with clay then was burnished with pebble and fired in reducing conditions at 750 °C.

The graphite coatings of these samples were compared with two Late Bronze Age samples from Tiszabura–Bónishát, Hungary (1310–1190 cal. BC), from where 65 graphite-coated ceramics were examined macroscopically and with a stereo microscope ($\times 20$ – 30) in order to assess how graphite coating may have been applied. The ceramics show that graphite seems to be applied directly onto vessel surfaces or as suspension, although different surface treatments were identified: streaks made by pebble burnishing and streaks/scratches made by an unknown material (leather, or other organic material). Since only two methods of applying graphite were identified on the ceramics, two samples representing these practices were chosen for SEM.

One amphora neck fragment (Inv.No. 2010.5.213.226/S285) shows marks of pebble-burnished graphite coating on its exterior, while its interior is not graphitic. This sample showed the highest luster among the examined ones. The second sample (Inv.No. 2010.5.213.223/S385), a rim of an amphora, shows graphitic suspension on its interior (it peeled off at places), while its exterior is also graphitic but it seems that graphite was directly applied onto the surface and no suspension was used. The surfaces of this vessel were worn, but some surface marks suggest pebble burnishing.

SEM indicates similarities between Sample 6 and the amphora neck (Inv.No. 2010.5.213.226/S285) in terms of graphite coating, although the archaeological sample shows thicker graphite on its exterior (Figs. 6.1a, 6.3a, 7.2–4, 7.6). SEM analysis also helped to assess how surface treatment affects the orientation and distribution of graphite on vessel surfaces. As it was mentioned earlier burnishing with pebble resulted the best cohesion between graphite and vessel surface during the experiment. According to the SEM analysis of Sample 6, pebble burnishing also oriented graphite flakes parallel to the vessel wall (Figs. 6.1a, 7.2–4). Similar orientation can be observed on the examined amphora neck that is assumed to be burnished with pebble (Figs. 6.3a, 7.6). Therefore, it seems likely that the examined ceramic was indeed burnished with pebble or at least with a hard and smooth object.

The suspension coating on the interior of an amphora rim (Inv.No. 2010.5.213.223/S385) also shows similarities to the experimental sample (23); the suspensions on both samples can clearly be identified by SEM (Figs. 6.2a, 6.5a, 8.2, 8.4, 8.6). The exterior of this urn is also graphitic, but graphite seems to be applied directly on the vessel surface and no suspension boundary could be identified. The thickness of graphite on the exterior shows similarities to that of the other amphora and the experimental sample.

Table 1
Firing circumstances of the samples.

Sample no.	Heating time	Soaking time	Firing condition	Maximum °C
1–4	90 min to 400 °C then 90 min to 700 °C in oxidizing conditions		Oxidizing	700
5, 10, 13, 16	90 min to 400 °C then 90 min to 700 °C in reducing conditions		Reducing	700
6, 11, 14, 17, 19–27	90 min to 400 °C then 90 min to 750 °C in reducing conditions	None, the kiln was switched off and let it cool	Reducing	750
7, 12, 15, 18	90 min to 400 °C then 90 min to 800 °C in reducing conditions		Reducing	800
8	90 min to 400 °C then 90 min to 900 °C in reducing conditions		Reducing	900
9	90 min to 400 °C then 90 min to 1000 °C in reducing conditions		Reducing	1000

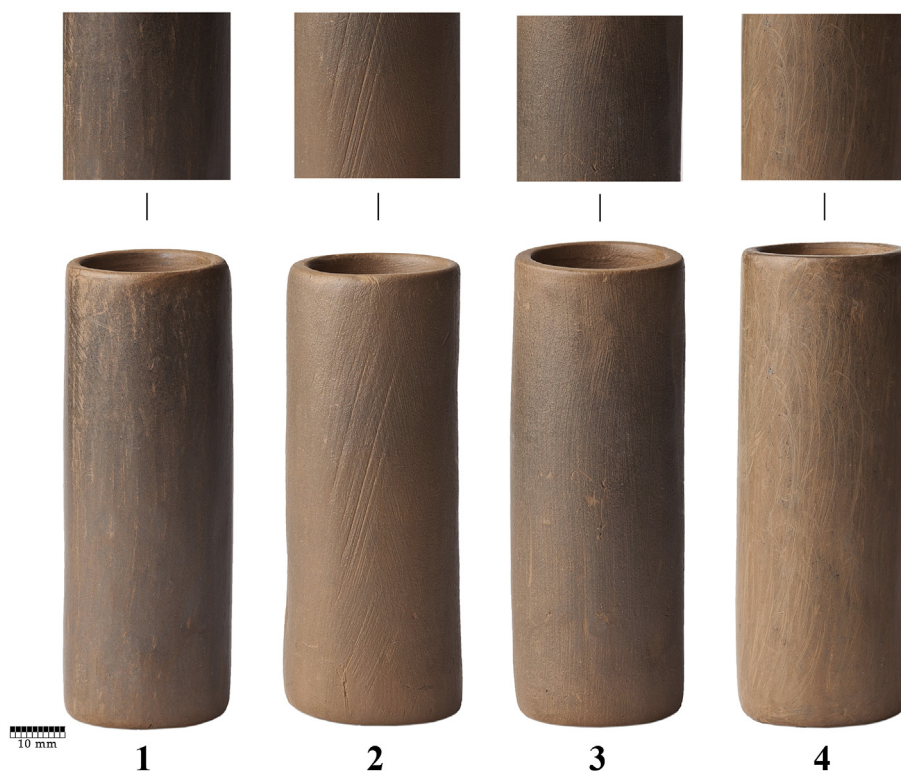


Fig. 3. Vessels fired in oxidized conditions at 700 °C (Samples 1–4). Note that the first, pebble-burnished, sample shows the most remaining graphite after firing.

It must be noted that macroscopically the vessels seem completely graphitic; however, according to the SEM analysis vessel surfaces are not entirely covered with graphite (Figs. 6.1b, 6.2b, 6.3b, 6.4b, 7.1, 7.5, 8.1, 8.5), which explains why the cross-section of the samples in the SEM do not always show continuous graphite coating. The amount and distribution of graphite on vessel surfaces affect the luster and metallic appearance of the vessels. It seems that when vessel surfaces are burnished with pebble (or with a hard and smooth tool), graphite flakes are distributed evenly on the surface irrelevant whether graphite powder or graphitic suspension was used (Figs. 6.1b, 6.3b, 7.1, 7.5, 8.1). For example, an apparent similarity in graphite distribution can be observed on Fig. 7.1 (graphite powder) and Fig. 8.1 (graphitic suspension). The exterior surface of one of the examined urns, which showed the highest luster among the examined ceramics,

exhibits relatively well-distributed graphite flakes (Fig. 6.3b). The exterior surface of the other urn is quite worn and less lustrous; the graphite distribution on this ceramic is less even may be due to use wear or post depositional circumstances (Figs. 6.4b, 8.5).

In summary, as a result of pebble burnishing, the orientation of graphite flakes and their even distribution on vessel surfaces enhanced the metallic luster of the vessels. Therefore, vessels made by this technique are the most reminiscent of metal vessels.

4. Discussion: recipe for making graphite-coated vessels with metallic luster

The range of experiments introduced in this study provides archaeologists with a fundamental tool in understanding how pre-historic potters may have made graphite-coated pottery and what

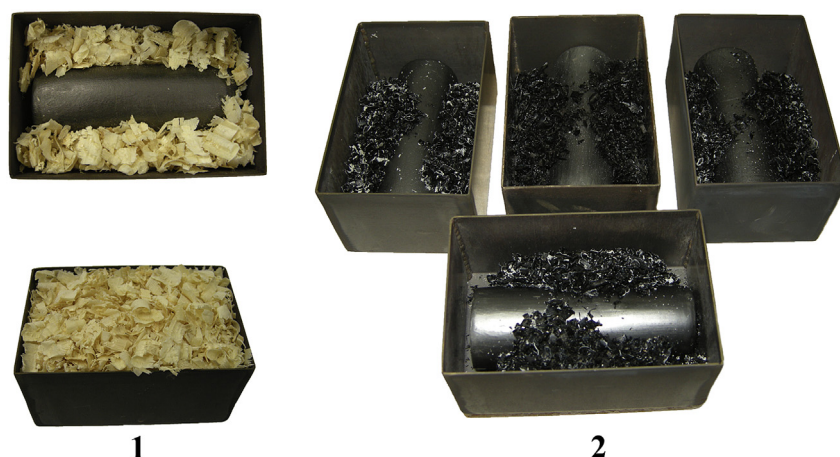


Fig. 4. 1. Preparing a sample for firing; 2. Samples after firing.



Fig. 5. Selection of fired samples (except Fig. 5.13) with different surface treatments. 1. Burnished with pebble (Sample 7); 2. Polished with sheep wool (Sample 12); 3. Polished with sheep leather (Sample 14); 4. Burnished with graphite lump (Sample 17); 5. Graphite powder applied on a dry surface then it was burnished with pebble (Sample 19); 6. Leather hard surface was burnished then it was rubbed with graphite powder (Sample 20); 7. Graphite powder was rubbed on a leather hard surface (Sample 21); 8. Leather hard surface was polished with sheep leather then it was covered with graphite powder and rubbed with the hand (Sample 22); 9. Suspension-coated (graphite + water) and burnished with pebble (Sample 27); 10. Suspension-coated (clay + graphite + water) and burnished with pebble (Sample 23); 11. Fired in reducing conditions, covered with graphite powder and burnished with pebble (Sample 24); 12. Fired in reducing conditions, covered with graphite powder and burnished with sheep leather (Sample 25); 13–15. Leather hard surface was burnished with pebble prior to graphite treatment (13) then it was fired in reducing conditions (14) and was rubbed with graphite powder (15) (Sample 26).

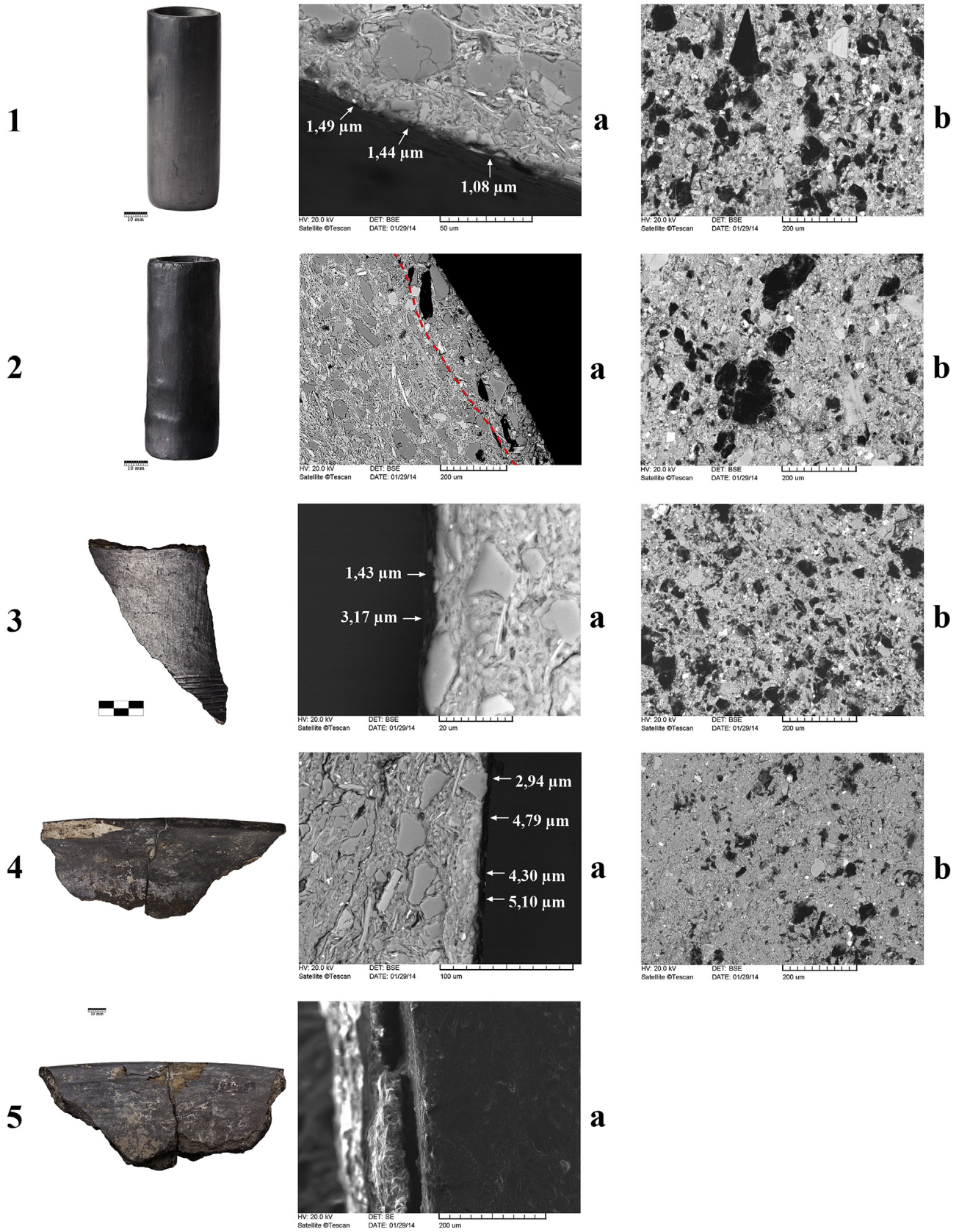


Fig. 6. 1. Pebble-burnished vessel (Sample 6): 1a. Thickness of graphite coating, 1b. Graphite distribution on the vessel surface; 2. Suspension-coated sample (Sample 23): 2a. The dashed line marks the thickness of suspension coating (the black inclusions are graphite flakes), 2b. Graphite distribution on the vessel surface; 3. Amphora neck fragment (Inv.No. 2010.5.213.226/S285): 3a. Thickness of graphite coating, 3b. Graphite distribution on the vessel surface; 4. Amphora rim fragment (Inv.No. 2010.5.213.223/S385) exterior: 4a. Thickness of graphite coating, 4b. Graphite distribution on the vessel surface. 5. Interior of the same amphora on Fig. 6.4. 5a. Thickness of clayey suspension. Note the non-graphitic parts between graphite flakes on Figs 6.1b, 6.2b, 6.3b, 6.4b.

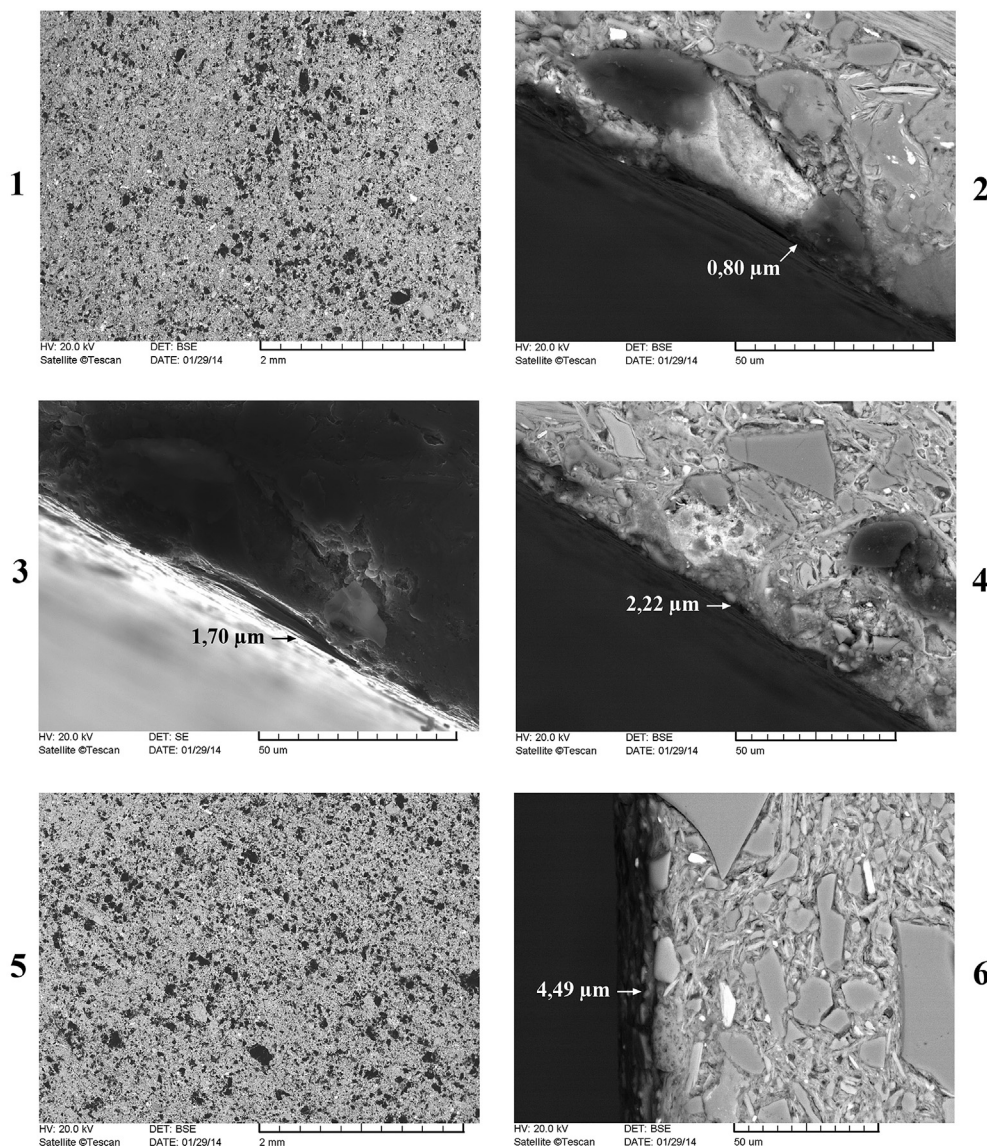


Fig. 7. 1. Graphite distribution on the surface of experimental Sample 6 (see Fig. 6.1b for a higher magnification image); 2–4. Thickness of graphite coating on experimental Sample 6 (see Fig. 6.1a for comparison); 5. Graphite distribution on the surface of the amphora neck (Inv.No. 2010.5.213.226/S285) (see Fig. 6.3b for a higher magnification image); 6. Thickness of graphite coating on the amphora neck (Inv.No. 2010.5.213.226/S285) (see Fig. 6.3b for comparison).

kind of technological challenges potters faced. The analysis of technical data derived from graphite coated archaeological ceramics compared with the results of this experiment has shown that we can clearly identify those practices which are the most appropriate for producing vessels with high luster. It seems that graphite can be applied before or after surface treatment as long as the surface is leather hard, although applying graphite before surface treatment is the most advantageous since surface treatment, in particular pebble burnishing, increased the bonding between graphite and clay. Graphite did not adhere properly on dry or fired vessels; these practices are disadvantageous and were probably not applied by prehistoric potters.

Both graphite powder and graphitic suspension were suitable methods of covering the vessels, although making a suspension seems to be an unnecessary step in the *production sequence* of graphite coating since the use of graphite powder has the same result while the use of suspension slows down ceramic production: after covering the vessel with suspension the vessel needs further

time to become leather hard again in order to utilize any surface treatment and differences in the thickness of the clayey suspension makes the vessel surface uneven and more difficult to burnish (see Fig. 6.10). Nevertheless, the use of clayey suspension could be identified at archaeological sites, just as at Tiszabura.

The use of pebble (or other hard and smooth tool) for burnishing graphite-coated vessels seems to be the ideal candidate to achieve the most lustrous surface. Archaeological samples reinforce this assumption showing narrow streaks made by a hard and smooth burnishing tool. Sheep leather and wool leave characteristic streaks and scratches on vessel surfaces, which could not be correlated with the marks found on the Tiszabura ceramics. The streaks and scratches on the Tiszabura ceramics are different, suggesting that different materials may have been used to polish these vessels (e.g. different type of leather/fur). Raw graphite, which seems to be a straightforward, readily available tool for making graphite-coated vessels (as crayon) turned out to be unsuitable for this practice. Nevertheless, rounded graphite prisms are found at excavations,

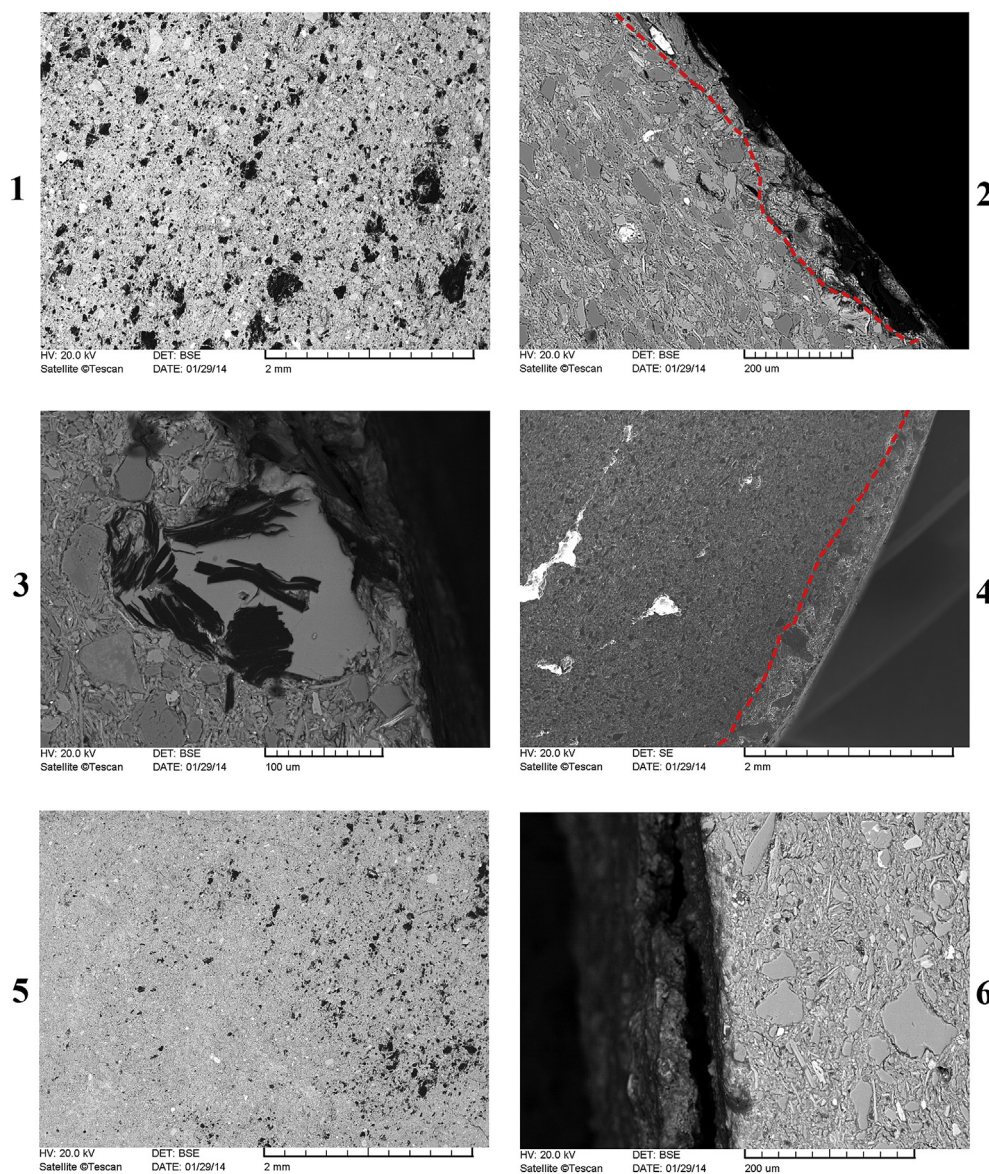


Fig. 8. 1. Graphite distribution on the surface of experimental Sample 23 (see Fig. 6.2b for a higher magnification image); 2. The dashed line marks the thickness of suspension coating on experimental Sample 23 (the black inclusions are graphite flakes, see Fig. 6.2a for comparison); 3. Graphite bearing rock within the suspension of experimental Sample 23; 4. The dashed line marks the thickness of easily distinguishable suspension coating on experimental Sample 23 (see Fig. 6.2a for comparison); 5. Graphite distribution on the exterior surface of the amphora rim (Inv.No. 2010.5.213.223/S385) (see Fig. 6.4b for a higher magnification image); 6. easily distinguishable suspension coating on the interior of the amphora rim (Inv.No. 2010.5.213.223/S385) (see Fig. 6.5a for comparison).

such as at Tiszabura. These prisms may have been the leftovers of graphite after grinding (See Fig. 1.3). Since in the Late Bronze Age Carpathian Basin graphite was only used to coat vessels and graphitic motifs did not exist, these graphite lumps may not have been used as crayons. In the Hallstatt period, however, apart from vessel coating, motifs *drawn* by graphite are also common. Therefore, the appearance of graphite prisms in this period could indicate that they may have been used to *draw* patterns of decorations.

According to the experiments, the best recipe for making graphite-coated pottery with the highest metallic luster is the following:

- Take some lumps of raw graphite and grind them on a grinding stone, or rub them against each other, or smash them with a stone. The finer the graphite powder the better it adheres to the vessel wall.

- Sprinkle the graphite powder on a leather hard vessel surface and rub it gently with the hand. A dry or already fired vessel is not suitable for applying graphite powder; graphite would not adhere properly to the vessel surface. Alternatively, you can apply graphitic suspension (either made of clay or without it).
- Burnish the leather hard vessel thoroughly with pebble. If you want to have a smoother surface use pebble burnishing gently then, while the vessel is still leather hard, rub the vessel by hand to smoothen out the pebble streaks.
- Let your vessel dry completely.
- Fire the vessel between 700 °C and 1000 °C in reducing conditions. Make sure that the atmosphere remains completely reduced all through the firing process otherwise graphite will burn off instantly.
- Leave the vessel in the ashes until the fire cools to accommodate as thorough a reduction as possible.

-Done! Now you have a vessel with a lustrous metallic appearance.

5. Conclusion

In this paper a range of experiments were conducted to improve our understanding of graphite coated ceramics in terms of graphite preparation, graphite coating, surface treatments prior to or after graphite coating, firing temperatures and atmospheres. The results of these experiments were compared with graphite coating on Late Bronze Age ceramics from Tiszabura, Hungary. The results show that graphite was applied directly on vessel surfaces probably as powder and also as a suspension mixed with clay. If graphite powder is applied directly on vessel surface, the surface must have been leather hard; dried or fired vessels are unsuitable for graphite coating. After graphite coating different surface treatments were used, although the most common seems to be pebble burnishing, and admittedly this process resulted in the highest metallic luster and the strongest bond between graphite and clay. Thus, there seems to be a direct correlation between metallic luster and surface treatment. The use of other materials that left scratches on vessel surfaces was also identified on the archaeological ceramics. However, these marks do not show apparent similarities to the marks on the experimental samples left by sheep leather, sheep wool and raw graphite lumps. Therefore, the utilization of other types of materials in prehistory can also be assumed (other types of leather, fur, or some other organic material). Graphite-coated vessels must have been fired in completely reducing conditions, which must have been maintained all through the firing process. There seems to be no relationship between metallic luster and firing temperature; vessels could have been fired in a wide range of temperatures, which was between 700 and 1000 °C during this experiment.

The results of these experiments suggest that the use of graphite to achieve lustrous metallic appearance requires a complex technological knowledge and a high level of skill. Moreover, the use of graphite in ceramic production, since graphite is only available in Hungary as graphite bearing phyllite which is unsuitable for graphite coating, implies large scale exchange, complex social networks, and communication of ideas and spread of technological knowledge. Therefore, the special technological knowledge and exotic nature of graphite (at least in Hungary) could have contributed to the social significance of graphitic wares and perhaps the social status of their makers. Assessment of the scale of production and identification of areas of production would shed more light on the social complexity of graphitic wares and their makers. However, the scale of pottery production could not be assessed since to date there is no published evidence for pottery production at any Late Bronze Age settlements. In order to define a pottery production site, one has to consider a series of attributes that may accompany ceramic production such as wasters, production tools, raw materials, structural evidence for the curing/mining of clay and the presence of distinctive manufacturing assemblages. According to any of these criteria, no Late Bronze Age pottery production sites have yet been found in Hungary. Nevertheless, graphite-coated ceramics, imitating the texture and appearance of metal vessels, could have been an effective means of social representations at feasts and burials (Vácz, 2013b).

Acknowledgments

We are grateful to Gábor Ilon for providing raw graphite for this experiment and to József Bicskei for the photographs.

Appendix 1

Sample no.	Condition of vessel	Surface treatment prior to graphite coating	Way of utilizing graphite	Surface treatment after graphite coating	Firing atmosphere	Firing temperature (°C)
1	Leather hard	None	In powder form prior to surface treatment and firing	Burnished with pebble prior to firing	Oxidizing	700
2	Leather hard	None	In powder form prior to surface treatment and firing	Polished with sheep wool prior to firing	Oxidizing	700
3	Leather hard	None	In powder form prior to surface treatment and firing	Polished with sheep leather prior to firing	Oxidizing	700
4	Leather hard	None	Raw graphite lump prior to firing	Burnished with raw graphite lump prior to firing	Oxidizing	700
5	Leather hard	None	In powder form prior to surface treatment and firing	Burnished with pebble prior to firing	Reducing	700
6	Leather hard	None	In powder form prior to surface treatment and firing	Burnished with pebble prior to firing	Reducing	750
7	Leather hard	None	In powder form prior to surface treatment and firing	Burnished with pebble prior to firing	Reducing	800
8	Leather hard	None	In powder form prior to surface treatment and firing	Burnished with pebble prior to firing	Reducing	900
9	Leather hard	None	In powder form prior to surface treatment and firing	Burnished with pebble prior to firing	Reducing	1000
10	Leather hard	None	In powder form prior to surface treatment and firing	Polished with sheep wool prior to firing	Reducing	700
11	Leather hard	None	In powder form prior to surface treatment and firing	Polished with sheep wool prior to firing	Reducing	750
12	Leather hard	None	In powder form prior to surface treatment and firing	Polished with sheep wool prior to firing	Reducing	800
13	Leather hard	none	In powder form prior to surface treatment and firing	Polished with sheep leather prior to firing	Reducing	700
14	Leather hard	None	In powder form prior to surface treatment and firing	Polished with sheep leather prior to firing	Reducing	750
15	Leather hard	None	In powder form prior to surface treatment and firing	Polished with sheep leather prior to firing	Reducing	800
16	Leather hard	None	Raw graphite lump prior to firing	Burnished with raw graphite lump prior to firing	Reducing	700

(continued)

Sample no.	Condition of vessel	Surface treatment prior to graphite coating	Way of utilizing graphite	Surface treatment after graphite coating	Firing atmosphere	Firing temperature (°C)
17	Leather hard	None	Raw graphite lump prior to firing	Burnished with raw graphite lump prior to firing	Reducing	750
18	Leather hard	None	Raw graphite lump prior to firing	Burnished with raw graphite lump prior to firing	Reducing	800
19	Completely dried	None	In powder form on a dry surface prior to surface treatment and firing	Dry, graphite-coated surface was burnished with pebble prior to firing	Reducing	750
20	Leather hard	Burnished with pebble prior to graphite coating	In powder form on a pebble burnished surface prior to firing	Rubbed with the hand	Reducing	750
21	Leather hard	None	In powder form on an untreated surface prior to firing	Rubbed with the hand	Reducing	750
22	Leather hard	Polished with sheep leather prior to graphite coating	In powder form on a leather polished surface prior to firing	Rubbed with the hand	Reducing	750
23	Leather hard	None	Suspension (10 g clay + 10 g fine to medium graphite powder + water) prior to firing	After suspension became leather hard it was burnished with pebble prior to firing	Reducing	750
24	Fired in reducing conditions prior to graphite coating	None	In powder form after firing	Burnished with pebble after firing	Reducing	750
25	Fired in reducing conditions prior to graphite coating	None	In powder form after firing	Polished with sheep leather after firing	Reducing	750
26	Leather hard	Burnished with pebble prior to firing	In powder form on a pebble burnished surface, after firing	Rubbed with the hand	Reducing	750
27	Leather hard	None	Suspension (10 g graphite powder + water) prior to firing	Burnished with pebble prior to firing	Reducing	750

References

- Berdels, E., 2002. Nachtöpfen von prähistorischer Keramik. Anzeiger Arbeitsgemeinschaft für Experimentelle Archäologie der Schweiz 2002, pp. 17–23.
- von Carnap-Bornheim, C., 1998. Graphit und Graphittonkeramik. In: Beck, H., Heinrich, G.D., Steuer, H. (Eds.), Reallexikon der Germanischen Altertumskunde, Band XII. Walter de Gruyter, Berlin – New York, pp. 593–598.
- Dobiat, C., 1980. Das hallstattzeitliche Gräberfeld von Kleinklein und seine Keramik. Schild von Steier: Beiträge zur steirischen Vor- und Frühgeschichte und Münzkunde, Beiheft 1. Abteilung für Vor- und Frühgeschichte und Münzensammlung am Landesmuseum Joanneum, Graz.
- Evans, R.K., 1986. The pottery of Phase III. In: Renfrew, C., Gimbutas, M., Elster, E. (Eds.), Excavations at Sitagroi. A Prehistoric Village in Northeast Greece, Monumenta Archaeologica 13, vol. 1. Institute of Archaeology University of California, Los Angeles, pp. 393–428.
- Frierman, J., 1969. Appendix II. The Balkan graphite ware. Proc. Prehist. Soc. XXXV (2), 42–44.
- Gáti, Cs., 2009. A szajki (Baranya megye) koravaskori telep kulturális kapcsolatai (Cultural contacts of the Early Iron Age settlement at Szajk, Baranya County). In: Ilon, G. (Ed.), ΜΩΜΟΣ VI. Proceedings of the 6th Meeting for the Researchers of Prehistory. Raw Materials and Trade. Field Service for Cultural Heritage – Vas County Museums' Directorate, Szombathely, pp. 65–77.
- Gebhard, R., Bott, R., Distler, N., Michálek, J., Riederer, J., Wagner, F.E., Wagner, U., 2004. Ceramics from the Celtic oppidum of Manching and its influence in Central Europe. Hyperfine Interact. 154, 199–214.
- Gróh, D., 1984. Előzetes jelentés a Visegrád–Csemetekert lelőhelyen végzett későbronzkori és koravaskori feltárásról (Vorbericht über die spätbronze- und früheisenzeitliche Erschließung von Visegrád–Csemetekert). Communicationes Archaeologicae Hungariae, pp. 53–66.
- Havancsák, I., Bajnóczi, B., Tóth, M., Kreiter, A., Szöllösi, Sz., 2009. Kelta grafitos kerámia: elmélet és gyakorlat dunaszentgyörgyi kerámiák ásványtani, petrográfiai és geokémiai vizsgálatának tükrében (Celtic graphitic pottery: theory and practice in the light of mineralogical, petrographic and geochemical study of ceramics from Dunaszentgyörgy, S-Hungary). Archeom. Műhely/Archeom. Workshop 6 (1), 39–52.
- Helgert, H., 1995. Grabfunde der Čaka-Kultur (BzD/Ha A1-Übergangsperiode) aus Zurndorf, p. B. Neusiedl am See, Burgenland. Ein Beitrag zur weiblichen Totentracht. Archaeol. Austriaca 74, 197–248.
- Jerem, E., Kardos, J., 1985. Entwicklung und Charakter der eisenzeitlichen Graphittonware. In: Mitteilungen der Österreichischen Arbeitsgemeinschaft für Ur- und Frühgeschichte, vol. 35, pp. 65–75.
- Kovács, T., 1975. Tumulus Culture Cemeteries of Tiszafüred. In: Régészeti Füzetek II/17. Hungarian National Museum, Budapest.
- Kreiter, A., Czifra, Sz., Széles, É., Tóth, M., Viktorik, O., 2013a. Petrographic, LA-ICP-MS and XRD analyses of Hallstatt ceramics from a Scythian Age settlement in north Hungary. In: Bergerbrant, S., Sabatini, S. (Eds.), Counterpoint: Essays in Archaeology and Heritage Studies in Honour of Professor Kristian Kristiansen. Archaeopress, Oxford, pp. 477–490. BAR IS 2508.
- Kreiter, A., Bartus-Szöllösi, Sz., Bajnóczi, B., Azbej Havancsák, I., Tóth, M., Szakmány, Gy., 2013b. Ceramic technology and the materiality of Celtic graphitic pottery. In: Alberti, M.E., Sabatini, S. (Eds.), Exchange Networks and Local Transformations. Interaction and Local Change in Europe and the Mediterranean from the Bronze Age to the Iron Age. Oxbow, Oxford, pp. 169–179.
- Kustár, R., 2000. Spätbronzezeitliches Hügelgrab in Isztimér-Csőszpuszta. Alba Regia 29, 7–53.
- Leshtakov, P., 2004. Graphite deposits and some aspects of graphite use and distribution in Bulgarian Chalcolithic. In: Nikolov, V., Bacvarov, K., Kalchev, P. (Eds.), Prehistoric Thrace. Proceedings of the International Symposium in Stara Zagora. Institute of Archaeology – Museum Sofia – Regional Museum of History Stara Zagora, Sofia – Stara Zagora, pp. 488–496.
- Lochner, M., 1986a. Das frühurnenfelderzeitliche Gräberfeld von Baierdorf, Niederösterreich – eine Gesamtdarstellung. Archaeol. Austriaca 70, 263–294.
- Lochner, M., 1986b. Ein urnenfelderzeitliches Keramikdepot aus Oberravelsbach, Niederösterreich. Archaeol. Austriaca 70, 295–315.
- Maniatis, J., Tite, M.S., 1981. Technological examinations of Neolithic–Bronze Age pottery from Central and Southeast Europe and from the Near East. J. Archaeol. Sci. 8, 59–76.
- Nebelsick, L.D., 1997. Trunk und Transzendenz. Trinkgeschirr im Grab zwischen der frühen Urnenfelder- und späten Hallstattzeit im Karpatenbecken. In: Becker, C., Dunkelman, M.L., Metzner-Nebelsick, C., Peter-Röcher, H., Roeder, M., Terzan, B. (Eds.), Χρόνος. Beiträge zur prähistorischen Archäologie zwischen Nord- und Südosteuropa. Festschrift für Bernhard Hänsel, Internationale Archäologie – Studia Honoraria 1. Verlag Marie Leidorf, Espelkamp, pp. 373–387.
- Papadopoulos, S., 2007. Decline of painted pottery in eastern Macedonian and north Aegean at the end of the final Neolithic/Chalcolithic period. In: Todorova, H., Stefanovich, M., Ivanov, G. (Eds.), The Struma/Strymon River Valley in Prehistory. Proceedings of the International Symposium Strymon Praehistoricus, In the Steps of James Harvey Gaul, vol. 2. Gerda Henkel Stiftung, Sofia, pp. 317–328.
- Pechtl, J., Eibl, F., 2011. Die neolithische Graphitnutzung in Südbayern. In: Schmotz, K. (Ed.), Vorträge des 29. Niederbayerischen Archäologentages. Verlag Maria Leidorf, Rahden, pp. 349–432.
- Podborský, V., 1970. Mähren in der Spätbronzezeit und an der Schwelle der Eisenzeit. Universita J. E. Purkyně, Brno.
- Rihovský, J., 1982. Das Urnenfelderfeld von Podolí. In: Fontes Archaeologiae Moraviae 15. Archeologický Ústav Akademie, Brno.

- Szabó, M., 2007. La chronologie de l'habitat. In: Szabó, M. (Ed.), *L'habitat de l'époque de La Tène à Sajópetri Hosszú-dűlő*. L'Harmattan, Budapest, pp. 313–319.
- Trebsche, P., 2011. Eisenzeitliche Graphittonkeramik im Mittleren Donauraum. In: Schmotz, K. (Ed.), *Vorträge des 29. Niederbayerischen Archäologentages*. Verlag Marie Leidorf, Rahden, pp. 449–481.
- V. Szabó, G., 2004. A tiszacsegei edénydepó. Újabb adatok a Tisza-vidéki késő bronzkori edénydeponálás szokásához (Das Gefäßdepot von Tiszacsege. Neue Angaben zur Sitte der spätbronzezeitlichen Gefäßdeponierung in der Theißgegend). *A Móra Ferenc Múzeum Évkönyve – Studia Archaeologica* 10, pp. 81–113.
- Vácz, G., 2013a. Burial of the Late Tumulus – Early Urnfield period from the vicinity of Nadap, Hungary. In: Anders, A., Kulcsár, G. (Eds.), *Moments in Time*. Papers Presented to Pál Raczky on His 60th Birthday, Prehistoric Studies 1. Prehistoric Society – Eötvös Loránd University, Budapest, pp. 817–830.
- Vácz, G., 2013b. Cultural connections and interactions of eastern Transdanubia during the Urnfield period. *Dissertationes Archaeologicae* 3/1. Eötvös Loránd University, Budapest, pp. 205–230 [online] Available at: <http://dissarch.elte.hu/index.php/dissarch/article/view/220> (accessed on 21.05.14.).
- Vajsov, I., 2007. Promachon-Topolnica. A typology of painted decorations and its use as a chronological marker. In: Todorova, H., Stefanovich, M., Ivanov, G. (Eds.), *The Struma/Strymon River Valley in Prehistory. Proceedings of the International Symposium Strymon Praehistoricus*, In the Steps of James Harvey Gaul, vol. 2. Gerda Henkel Stiftung, Sofia, pp. 79–120.
- Yiouni, P., 2000. Painted pottery from east Macedonia in North Greece: technological analysis of decorative techniques. *Doc. Praehist.* 27, 199–214.